OECD GLOBAL SCIENCE FORUM
WORKSHOP ON METHODOLOGIES AND TOOLS FOR ASSESSING SOCIO-ECONOMIC IMPACT OF RESEARCH INFRASTRUCTURES
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A CBA MODEL FOR RESEARCH INFRASTRUCTURES

The case of the Large Hadron Collider LHC at CERN

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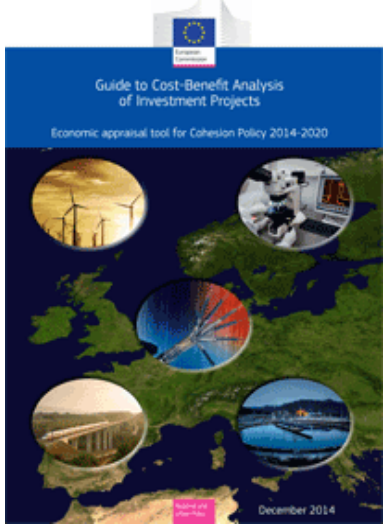


CBA FOR RESEARCH INFRASTRUCTURES

Some information on CBA international practice are drawn from the results of a survey conducted on ***selected OECD countries*** addressing the actual use, practice and role of CBA in ex-ante project appraisal.

OECD, Government at glance

July 2015

http://www.oecd.org/gov/govataglance.htm

Rail *(e.g. Austria, Denmark, Canada, Sweden, Netherlands).*

Urban transport *(e.g. New Zealand, Austria, Denmark, Canada, Sweden, Netherlands)*

Airports, ports and waterways *(e.g. Austria, Canada, Sweden, Netherlands, UK)*

Education *(e.g. Canada, UK)*

Culture and leisure *(e.g. New Zealand, Canada, UK)*

Water supply and wastewater *(e.g. Canada, Netherlands)*

Solid waste management *(e.g. Canada, UK)*

Other environmental projects: risk prevention and mitigation, natural asset conservation, etc. (e.g. *Canada, Sweden, UK)*

ICT: telecommunications, broadband, ICT applications to businesses and citizens *(e.g. Canada, UK)*

Health *(e.g. Canada, Sweden)*

Energy: production, transmission and distribution (e.g. Denmark, Canada, Sweden)

Scientific research (e.g. Canada, UK)

Technological development and innovation: science parks, technological parks, incubators, etc. *(e.g. Canada, UK)*

THE CBA MODEL

$$\mathbb{E}\,(NPV_{RDI}) = \mathbb{E}(PV_{B_u}) + \mathbb{E}(PV_{B_n}) - \mathbb{E}(PV_{C_u})$$

B_u

= Technological spillovers
+ Human capital formation
+ Social benefits to consumers of services
+ Knowledge creation
+ Cultural effects

B_n

= Existence value
+ Quasi option value

C_u

= Investments
+ Operative costs

- The E(NPV) of research infrastructures over the ***time horizon*** $\mathcal{T}$ is defined as the expected difference between ***benefits*** and ***costs*** valued at shadow prices and discounted at the ***social discount rate r .***

- It can be decomposed in two parts: the ***expected net present value of use-benefits*** and ***costs*** NPV_u and the ***expected (non-use) social value of discovery*** B_n**.**

- We drop the expectation operator, but ***all variables are to be considered as stochastic***.

- Applications: ***Large Hadron Collider*** (CERN) and ***National Hadrontherapy Center for Cancer Treatment*** (CNAO).

COSTS AND BENEFITS

The present value of COSTS PV_{C_u}

is the sum of the:

- **economic value of capital** (K)
- **labour cost of scientists** (L_s)
- other **administrative and technical staff** (L_o)
- other **operating costs** (O)
- **negative externalities** if any (E).

The present value of BENEFITS PV_{B_u}

is the sum of the:

- **Firms** (T)
- **Employees** (H)
- **Consumers/Users** ***(A + S + C)***

B_u

- **Taxpayers** $(QOV + EXV)$

B_n

$$PV_{C_u} = \sum_{t=0}^{\mathcal{T}} s_t \cdot (k_t + l_{st} + l_{ot} + \varepsilon_t)$$

$$PV_{B_u} = \sum_{t=0}^{\mathcal{T}} s_t \cdot (T_t + H_t + A_t + S_t + C_t)$$

$$S_t = \frac{1}{(1+i)^t}$$

i= discount rate

$$B_n = (QOV + EXV)$$

BENEFITS

USE BENEFITS PV_{B_u}

FIRMS

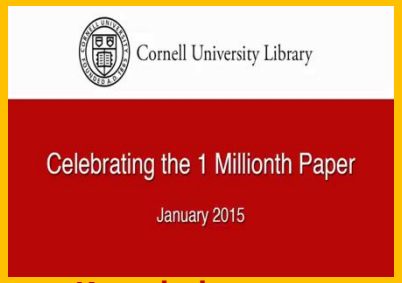
Technological externalities (T_t)

EMPLOYEES

Human capital formation (H_t)

CONSUMERS/USERS

Social benefits to consumers of services (A_t)



Knowledge output (S_t)

Cultural effects (C_t)

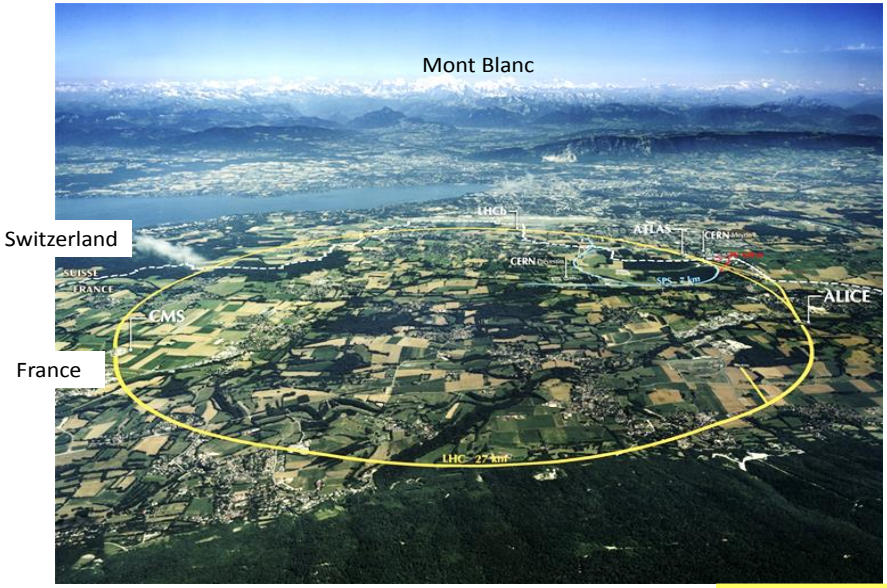
NON-USE BENEFITS Bn

TAXPAYERS

Quasi-option value (QOV)

Existence value (EXV)

EVIDENCE FROM A CASE STUDY: THE LHC

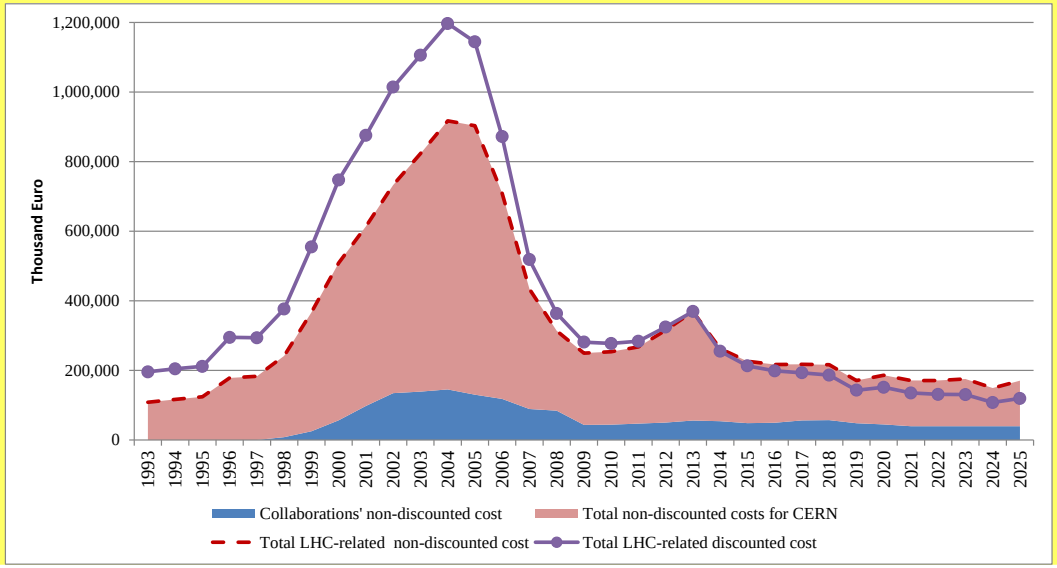


- The **Large Hadron Collider** (LHC) was built (1993-2008) by CERN.
- It is located in a **27 km-long** underground tunnel near Geneva.
- In operation since 2009, its main goal was achieved thanks to the discovery of the **Higgs boson** in 2013.

PARAMETERS FOR THE CBA

TIME HORIZON	33 years: 1993 - 2025
UNIT OF ANALYSIS	the LHC and its experimental facilities
SOCIAL DISCOUNT RATE	3% in real terms (adopted by the EC CBA Guide, 2014)
SHADOW PRICES	Proxied by marginal WTP or marginal costs
COUNTERFACTUAL	Business as usual scenario
QUASI-OPTION VALUE	assumed 0
NEGATIVE EXTERNALITIES	assumed 0

TOTAL DISCOUNTED AND NON-DISCOUNTED LHC COSTS COVERED BY CERN AND COLLABORATIONS, INCLUDING IN-KIND, BY YEAR (1993-2025; THOUSAND EURO)



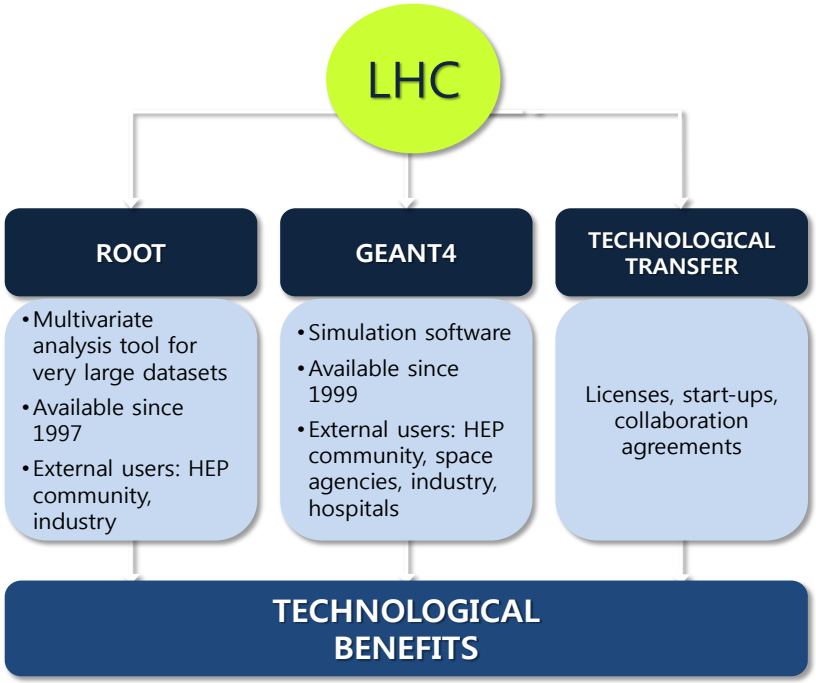
TECHNOLOGICAL EXTERNALITIES

The present value of technological spillovers (T_t) is given by:

- the ***discounted incremental social profits*** Π_{jt} generated by ***companies (j)*** of the RI's supply chain which have benefitted from a learning effect;
- and ***other externalities***.

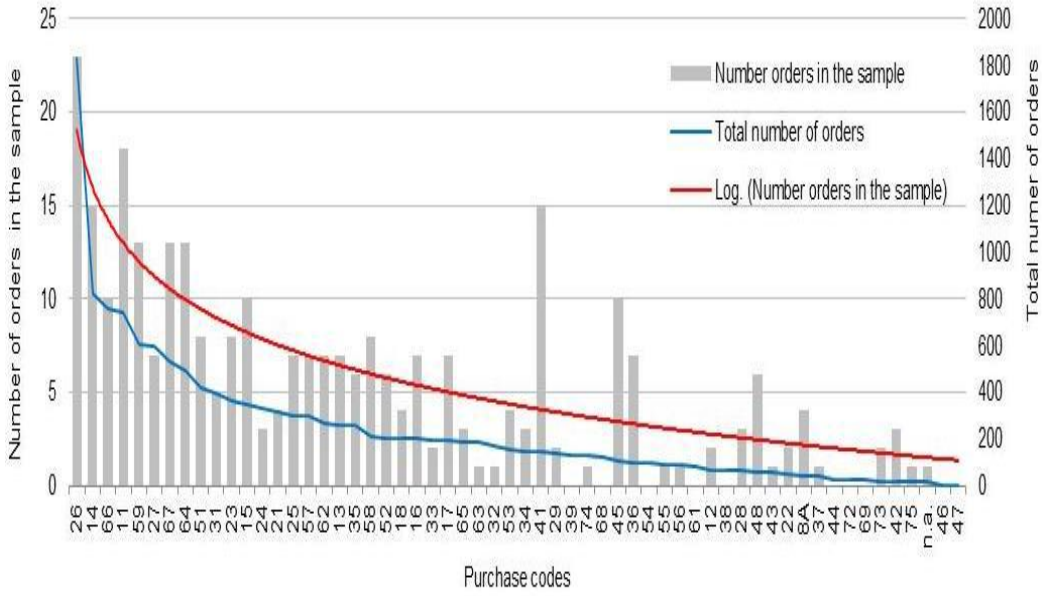
$$T = \sum_{j=1}^{J} \sum_{t=0}^{\mathcal{T}} s_t \cdot \Pi_{jt}$$

Benefits to software users



Benefits to suppliers

Sample of 300 orders by purchase code Compared with all LHC orders



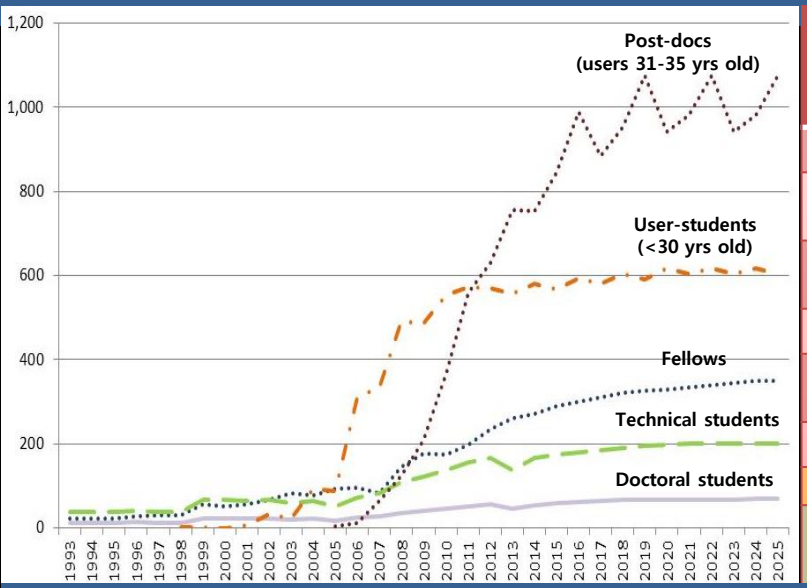
HUMAN CAPITAL FORMATION

Human capital formation benefits (H) are valued as ***increased earnings*** ($\boldsymbol{I}$) gained by RI's students and ***former employees*** ($\boldsymbol{z}$), since the ***moment*** ($\boldsymbol{\varphi}$) they leave the project, against ***counterfactual scenario***.

$$H = \sum_{z=1}^{z} \sum_{t=\varphi}^{\mathcal{T}} s_t \cdot I_{zt}$$

HUMAN CAPITAL FORMATION
Estimate for LHC

TYPES AND NUMBER OF PEOPLE BENEFITTING FROM TRAINING



TYPES AND QUANTITIES OF PEOPLE BENEFITTING FROM TRAINING

Variable	Number over the 1993-2025 period	Average staying at CERN
CERN fellows working on LHC	5,873	2 years
CERN technical students working on LHC	3,940	1 year
CERN doctoral students working on LHC	1,332	3 years
User-students working on LHC	14,225	3 years
Post-doc researchers (users) working on LHC	11,301	2 years
TOTAL	36,671	

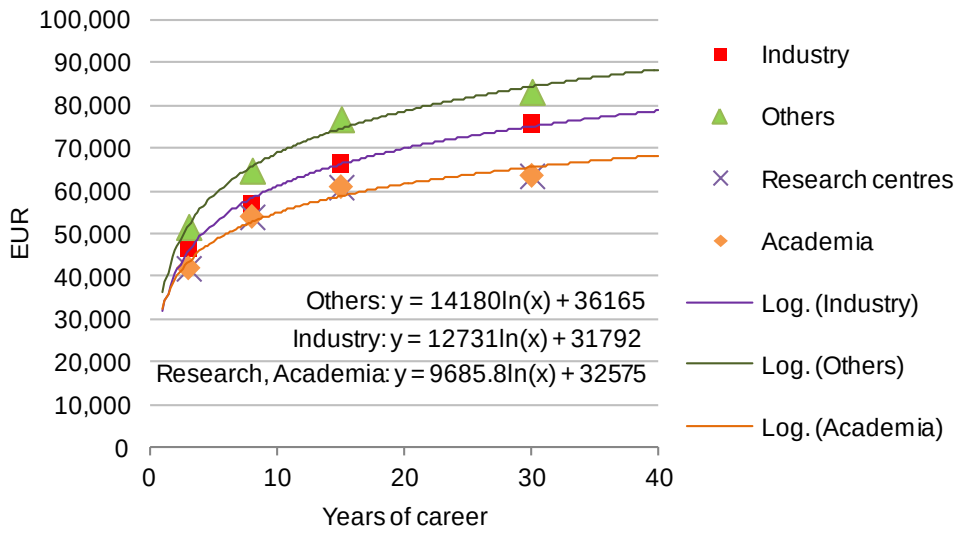
Sources: - CERN personnel statistics; - Interviews to CERN staff

Main assumptions: - Future number of beneficiaries; - Number of users-students and post-docs among users (assumed based on their age group); - Incoming number of user-students and post docs

ASSUMED DISTRIBUTION OF FORMER LHC STUDENTS BY PROFESSIONAL SECTOR

Sector	CERN fellows	CERN technical students	CERN doctoral students	User-students and post-docs
Industry	20%	45%	20%	20%
Others (computing, finance, public administration, …)	20%	45%	20%	20%
Research centres	30%	5%	30%	30%
Academia	30%	5%	30%	30%
TOTAL	**100%**	**100%**	**100%**	**100%**

ESTIMATION OF FUTURE AVERAGE SALARIES



DETERMINING THE RETURN TO SALARY DUE TO LHC TRAINING

Sector	SALARY EFFECT (1)	SALARY BONUS FOR JOB EFFECT (2)
	CERN fellows, doctoral students, user students, post-docs / CERN technical students	
Research centres Academia Industry Others (computing, financial, …)	9.3%	2.5%

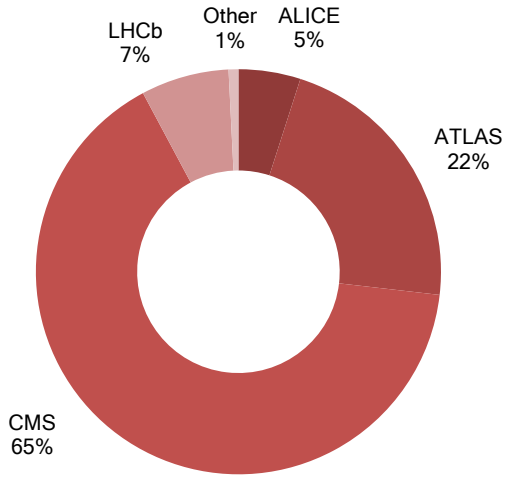
(1) Survey to 192 former LHC students (out of a total survey to 385 students and former students): declared salary impact of the experience at LHC on their current salary
(2) Own assumption based on survey results and Payscale salaries

Main source:
Findings from the survey to LHC current and former students

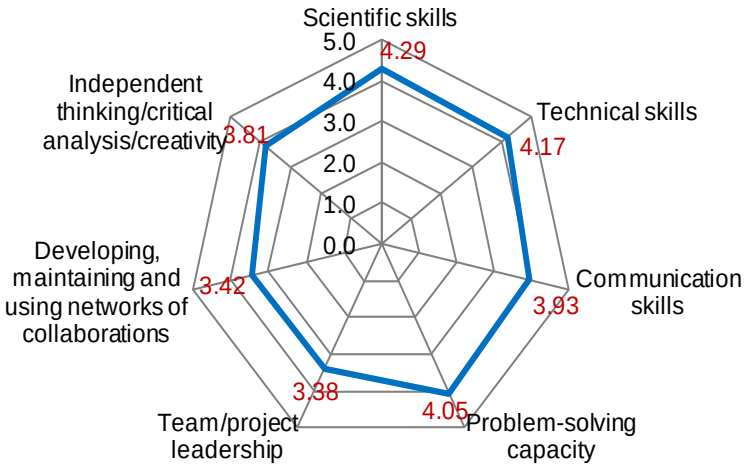
Main assumptions:
- Same economic return regardless of the professional sector and type of student
- Same return over the entire work career (40 yrs)

HUMAN CAPITAL FORMATION
Estimate for LHC

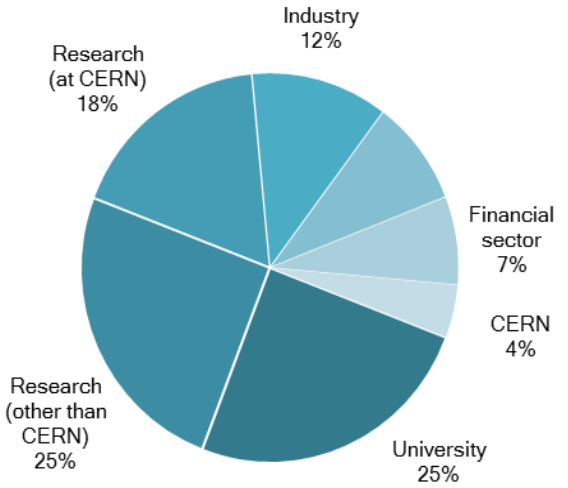
SHARE OF RESPONDENTS BY EXPERIMENT



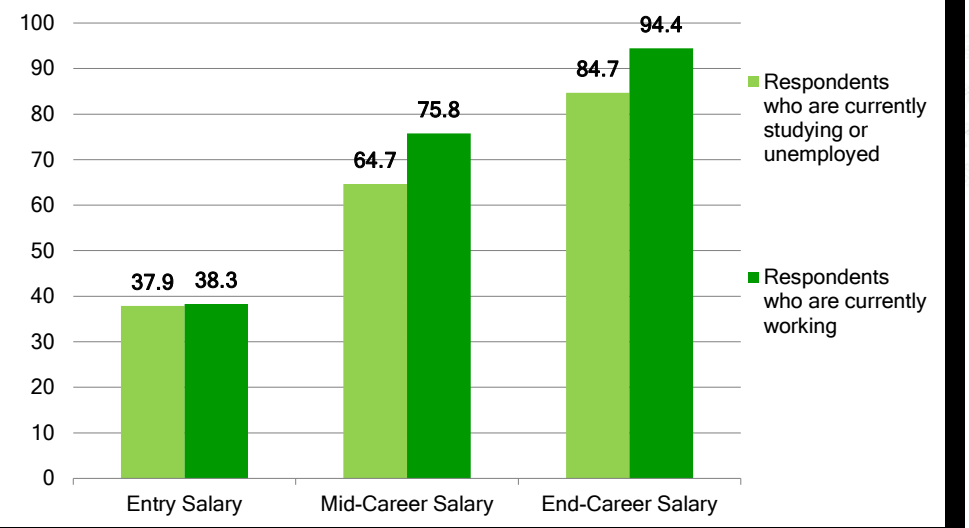
SKILLS IMPROVED THANKS TO THE LHC EXPERIENCE. AVERAGE JUDGEMENT



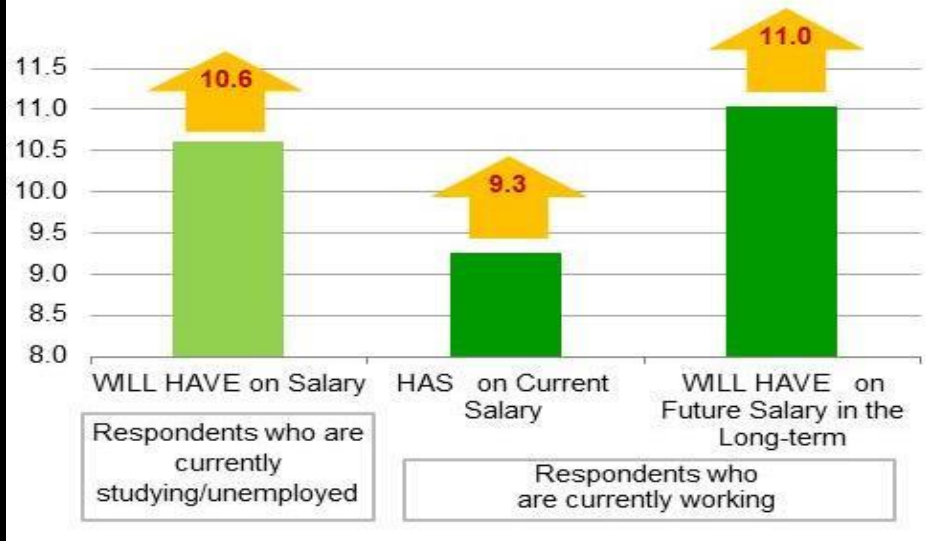
AN OVERVIEW OF CURRENT EMPLOYMENT SECTOR. SHARE OF RESPONDENTS



AVERAGE SALARY EVOLUTION: A COMPARISON BETWEEN THE TWO GROUPS OF RESPONDENTS (THOUSAND EUR)



THE IMPACT OF LHC EXPERIENCE ON SALARY (%)



KNOWLEDGE OUTPUT

The social value of knowledge output is measured by:

- the ***sum of the present value of papers signed*** by RI's scientists (P_{0t}) and the ***value of subsequent flows*** of papers produced by other scientists that use or elaborate of the RI's scientists' results
- ***divided by the number of references*** they contain ($\frac{P_{it}}{k_{it}}$, with $i = 1, \dots n$) and the ***value of citations each paper receives***, as a proxy of the social recognition that the scientific community acknowledges to the paper (Q_{it} with $i = 0, \dots n$)

$$S = \sum_{t=0}^{\mathcal{T}} s_t \cdot P_{0t} + \sum_{i=1}^{n} \sum_{t=1}^{\mathcal{T}} \frac{s_t \cdot P_{it}}{k_{it}} + \sum_{i=0}^{n} \sum_{t=1}^{\mathcal{T}} s_t \cdot Q_{it}$$

Cornell University Library

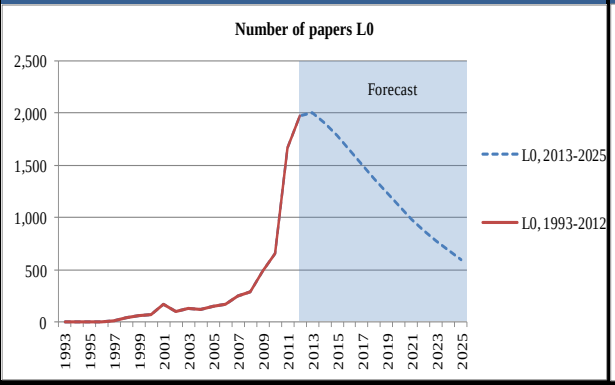
Celebrating the 1 Millionth Paper

January 2015

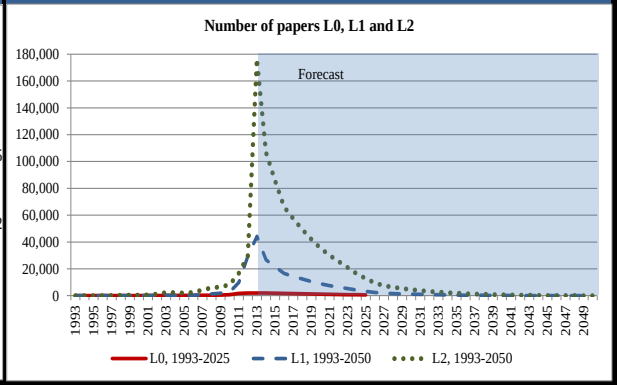
KNOWLEDGE OUTPUT OF LHC

Estimate for LHC

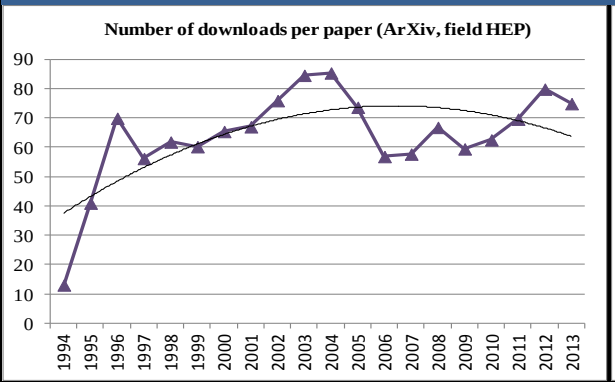
PAPERS PRODUCED BY LHC USERS (L0)

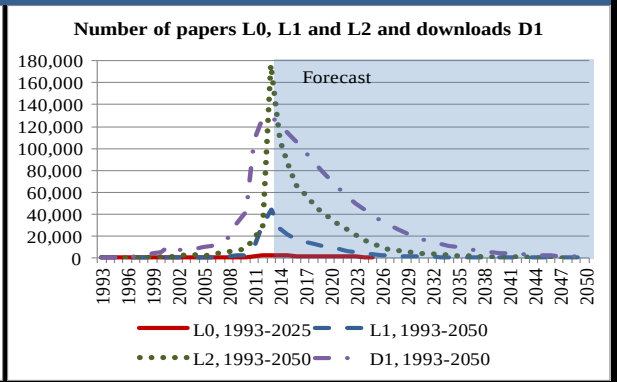


PAPERS PRODUCED BY NON-LHC USERS (L1 & L2)

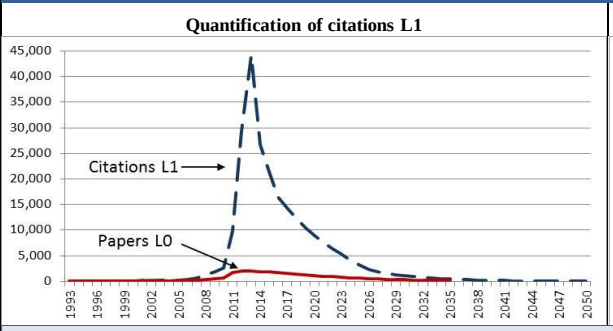


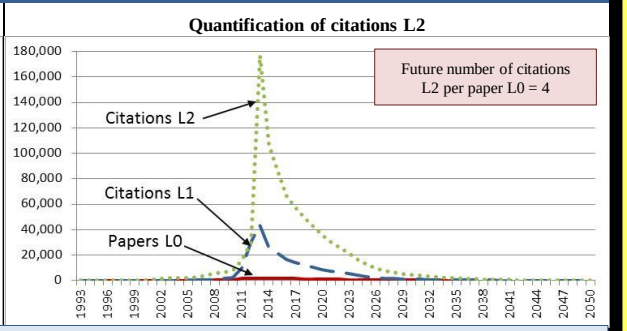
DOWNLOADS OF LHC PAPERS (D1)





TRACKING THE KNOWLEDGE OUTPUTS





Source: Preliminary scientometric analysis of INSPIRE database of papers and citations

VALUATION

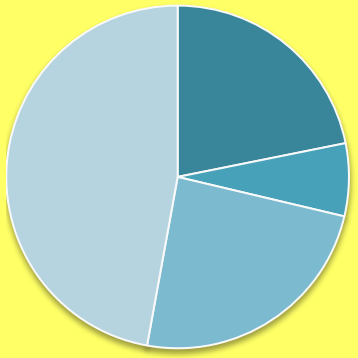
Unit economic value of papers L1

	Value	Source
Number of references in paper L1	35	Own assumption, based on an analysis of 41 research journals by Abt and Garfield (2002)
Share of time dedicated to research	65%	Own assumption. The remainder is for teaching and other non scientific activities
Number of paper (published and non) per year	3.5	Own assumption. It represents the number of papers to wich a scientist gives a real contribution
Average annual gross salary	59,289 €	Own elaboration based on PayScale data. It is the average salary for a scientists working in research centres and academia in the USA
Unit production cost per paper L1	315 € = (59,289 € * 65%/3.5/35)	Own estimation, based on the approach suggested by Florio and Sirtori (2014)

Unit economic value of citations and downloads

	Value	Source
Working hours per year	1,800 = 225 working days * 8 hours/day	Own assumption
Average hourly gross salary	33 € = 59,289/1,800	Own estimation
Hours per citation	3	Own assumption
Hours per download	3	Own assumption
Value of one citation L1 and L2	99 € = 33 € * 3	Own estimation, based on Florio and Sirtori (2014)
Value of one L0 paper downloaded but non cited	99 € = 33 € * 3	Own estimation, based on Florio and Sirtori (2014)

OUR RESULTS



Except L_0

CULTURAL EFFECTS

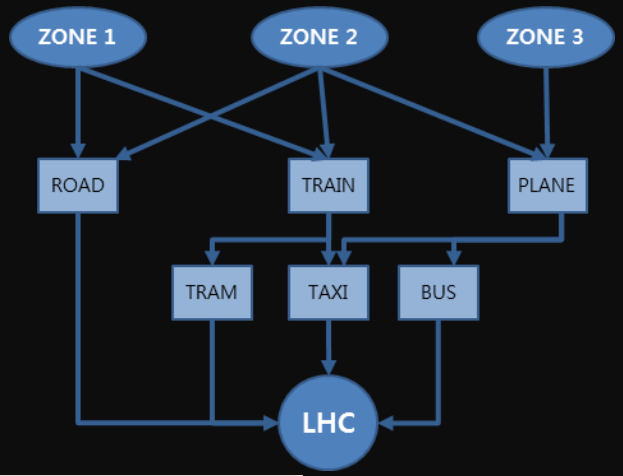
Outreach activities carried out by RI produce **cultural effects** on the general public (g), which can be valued by estimating the ***willingness to pay*** W_{gt} ***of the general public*** for such activities.

$$C = \sum_{g=1}^{G} \sum_{t=1}^{T} s_t \cdot W_{gt}$$

CULTURAL EFFECTS
Estimate for LHC

TRAVEL ZONES CONSIDERED

VALUATION THROUGH THE TRAVEL COST METHOD

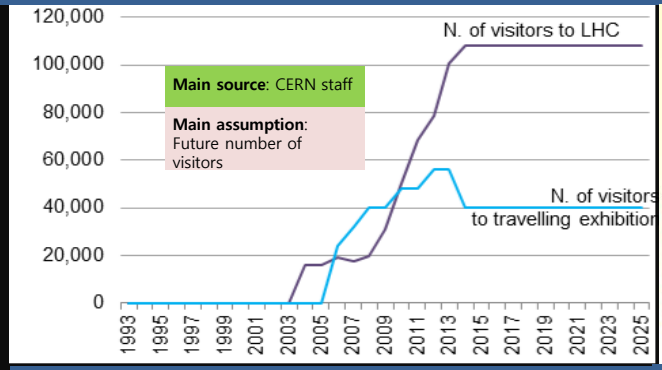


Main assumption:
- % of visitors by mode of transport
- Travel cost by zone

Source: HEATCO values of travel time by modes of transport

Origin zone	Radius distance from CERN	Share of visitors	Source/ Assumption
Zone 1	500 km	24%	CERN
Zone 2	500-1,500 km	50%	Own assumption
Zone 3	Beyond 1,500 km	26%	Own assumption

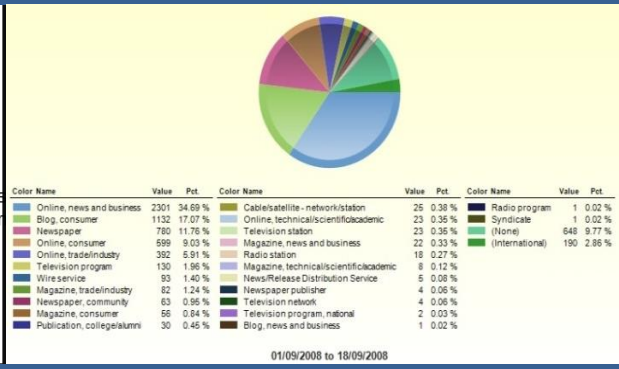
BENEFITS TO PERSONAL VISITORS: QUANTIFICATION OF VISITORS



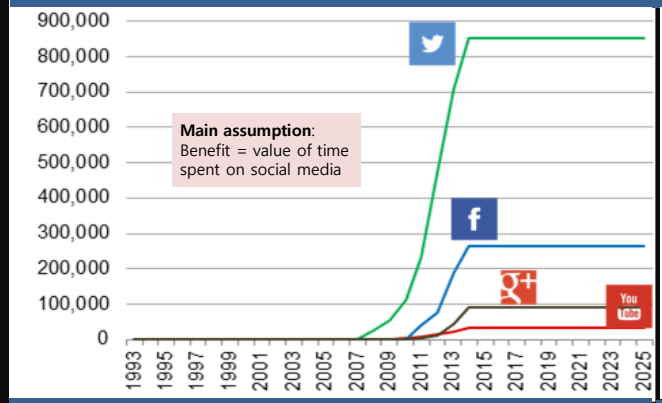
Main source: CERN staff

Main assumption: Future number of visitors

MASS MEDIA BENEFITS: NEWS BY MEDIA CHART

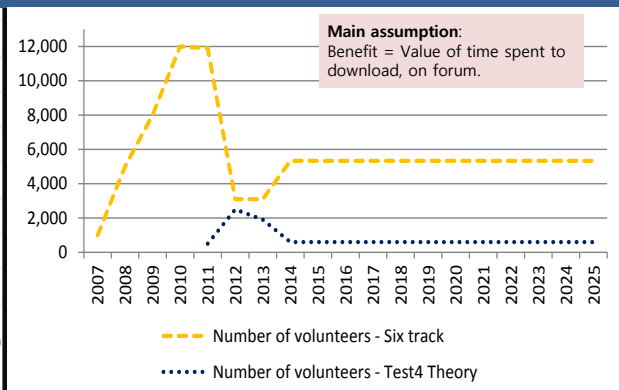


BENEFIT FOR SOCIAL MEDIA USERS



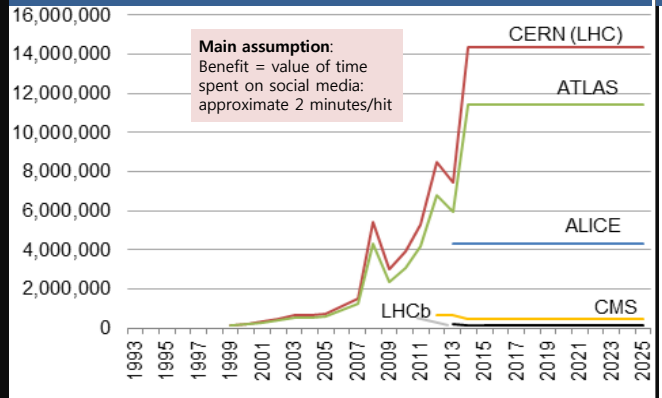
Main assumption: Benefit = value of time spent on social media

BENEFIT FOR VOLUNTEER COMPUTING



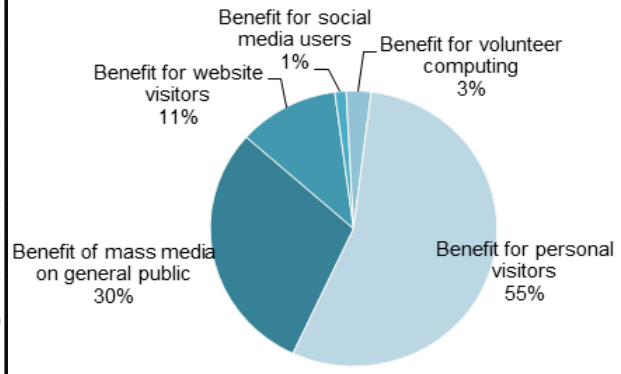
Main assumption: Benefit = Value of time spent to download, on forum.

BENEFIT FOR WEBSITE VISITORS



Main assumption: Benefit = value of time spent on social media: approximate 2 minutes/hit

SHARE OF BENEFITS BY TYPE OF OUTREACH ACTIVITY



THE NON-USE BENEFITS

B_n captures two types of benefits related to the social value of discovery:

the **quasi-option value** *(QOV)* and the **existence value** *(EXV)*:

where

- ***QOV*** is intrinsically ***uncertain*** and therefore ***not measurable***, simply assumed to be ***non-negative*** and then ***skipped***;
- ***EXV***, on the other hand, can be proxied by ***stated or revealed willingness*** to pay for scientific research, and/or through ***benefit transfer***, borrowing ideas from CBA of the environment.

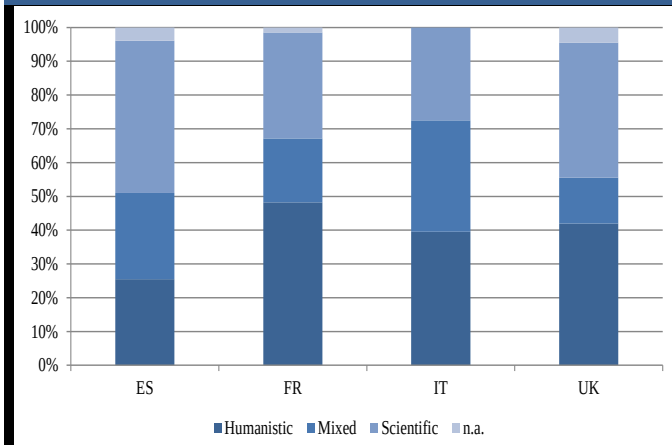
$$B_n = QOV + EXV$$

THE NON-USE BENEFITS

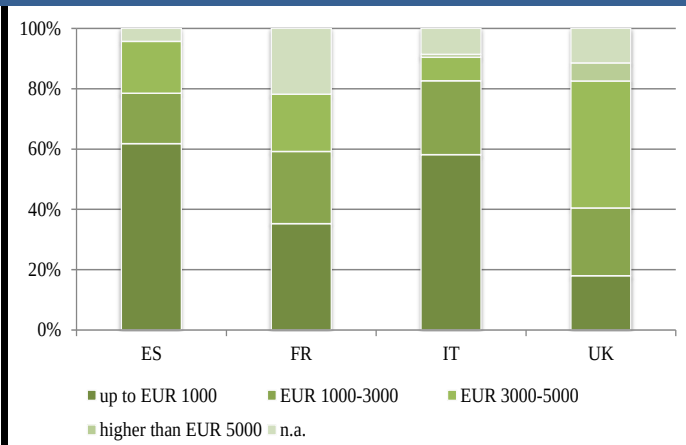
Estimate for LHC: Results from a contingent valuation

GENDER	Number
Female	*581*
Male	*446*
Total	*1027*
COUNTRY	**Number**
Italy	*422*
Spain	*204*
France	*201*
UK	*200*
Total	*1027*
YEARS	**Number**
19-25 years	*875*
26-30 years	*95*
31-35 years	*34*
Over 35 years	*20*
n.a.	*3*
Total	*1027*

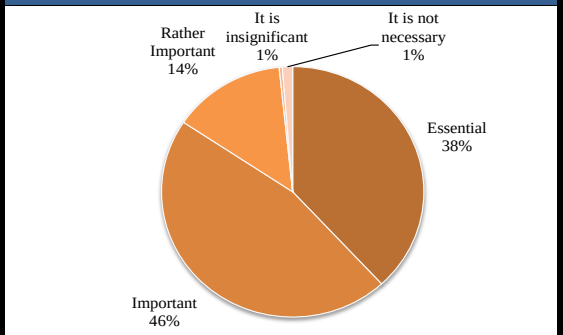
RESPONDENTS BY UNIVERSITY DEGREE



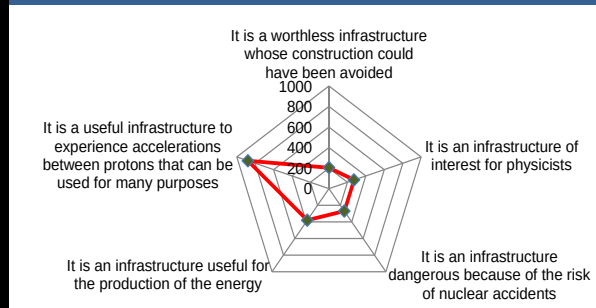
RESPONDENTS BY LEVEL OF HOUSEHOLD INCOME



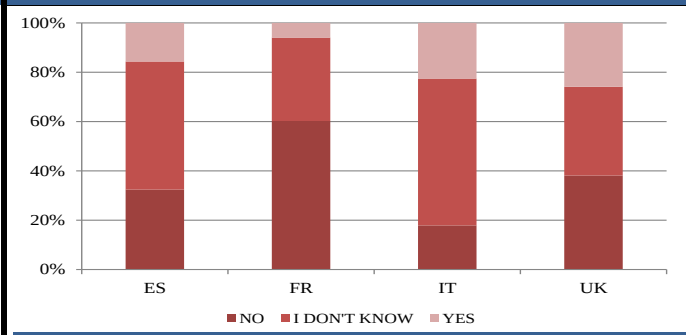
RATING THE IMPORTANCE TO FINANCE RDI



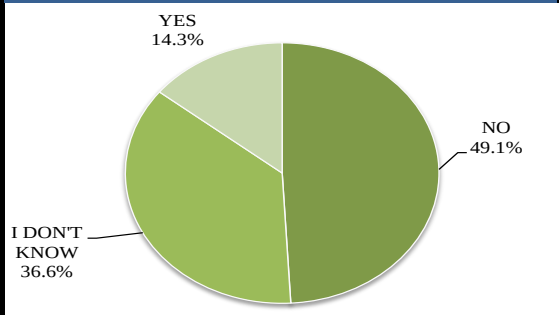
WHAT IS THE UTILITY OF THE LHC



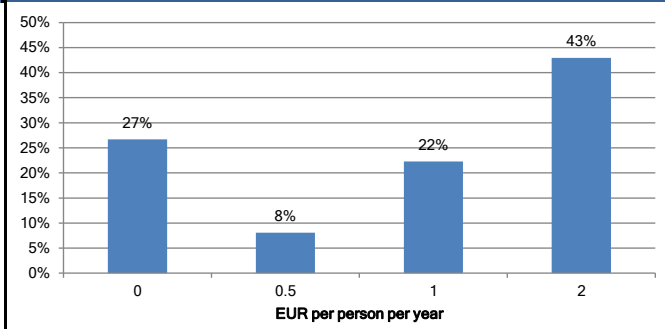
WILLINGNESS TO PAY FOR LHC



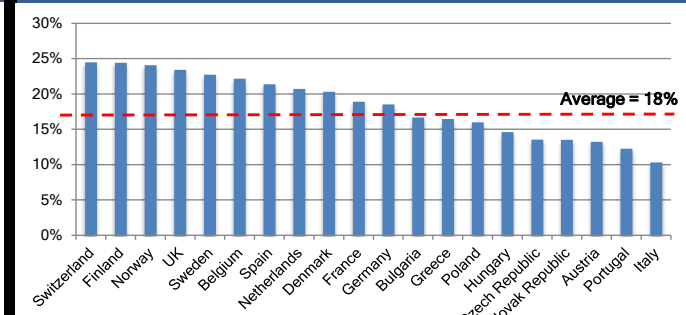
WTP TO PAY *UNA TANTUM*



AVERAGE ANNUAL WTP

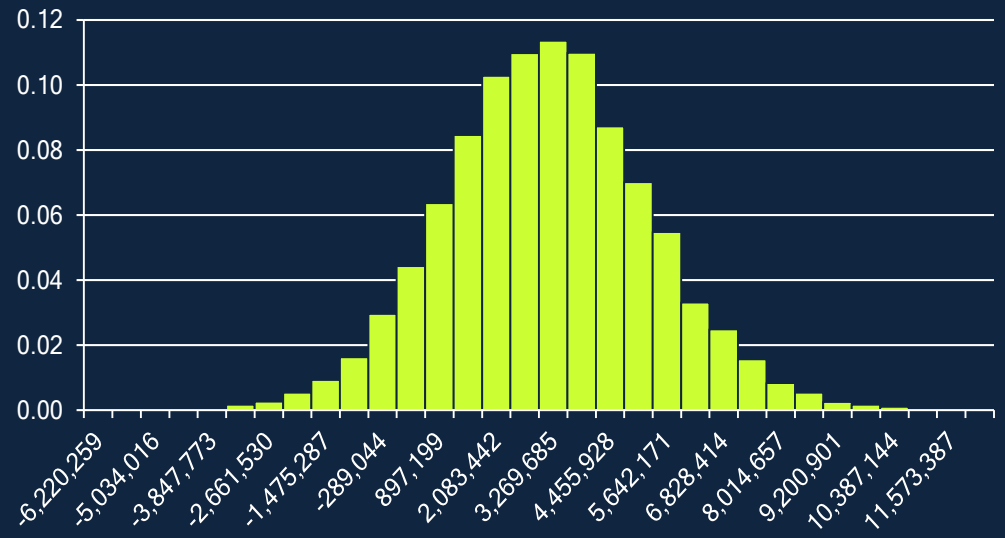


SHARE OF ADULT POPULATION (18-74 YEARS OLD) WITH AT LEAST TERTIARY EDUCATION

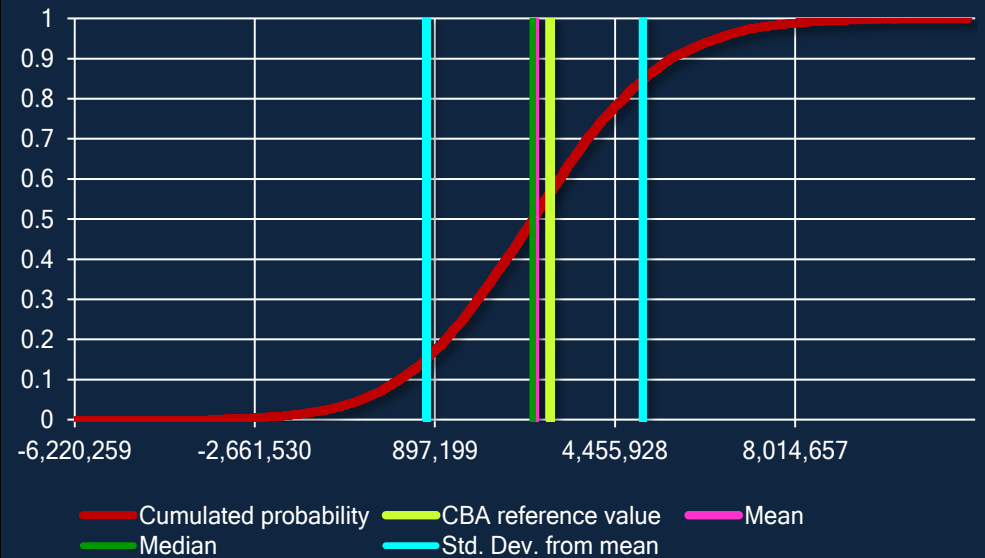


CONCLUSIONS

PROBABILITY DENSITY FUNCTION



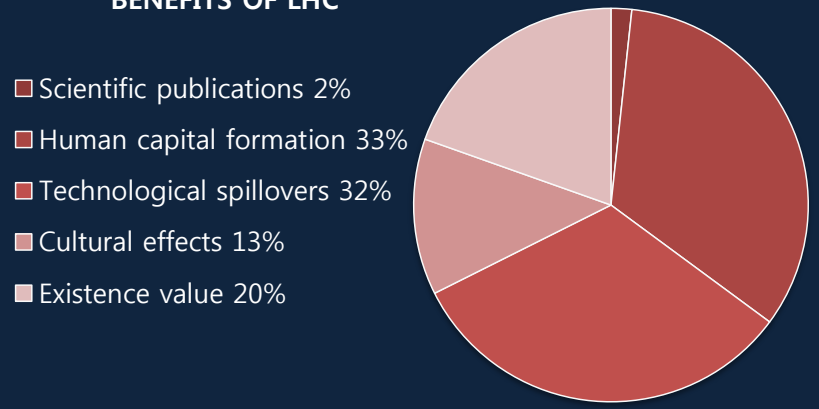
CUMULATIVE DISTRIBUTION FUNCTION



PROBABILITY DISTRIBUTION OF THE LHC NET PRESENT VALUE

Own estimate of the Present Value PDF resulting from a Monte Carlo simulation (10,000 random extractions)

TOTAL MEASURED BENEFITS OF LHC



ESTIMATED PARAMETERS OF DISTRIBUTION

Mean	2,855,528
Median	2,825,860
Standard deviation	2,134,763
Minimum	-6,220,259
Maximun	11,573,387

ESTIMATED PROBABILITIES

Pr. ENPV ≤ 0	0.086

THANK YOU

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To know more

http://www.eiburs.unimi.it/

Florio, M., Forte, S. and Sirtori, E. (2015), ***Cost-Benefit Analysis of the Large Hadron Collider to 2025 and Beyond***, arXiv:1507.05638v1 [physics.soc-ph] 20 Jul 2015.

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http://wp.demm.unimi.it/tl_files/wp/2015/DEMM-2015_05wp.pdf

Florio, M., Pancotti, C., Sirtori, E. and Vignetti, S. (2015), ***Exploring Cost-Benefit Analysis of Research, Development and Innovation Infrastructures: An Evaluation Framework***, discussion paper.

to be presented at

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